THE 1998-2000 ARCHEOLOGICAL SURVEYS RELATED TO PRESCRIBED AND WILDLAND FIRE COMPLIANCE IN THE NORTHERN CALIFORNIA SUBCLUSTER, LASSEN VOLCANIC NATIONAL PARK, LAVA BEDS NATIONAL MONUMENT, AND WHISKEYTOWN NATIONAL RECREATION AREA

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EPISTEMOLOGY

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TABLE OF CONTENTS

Introduction ....

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CHAPTER 1
INTRODUCTION

Fire has been a powerful force in North America through the duration of its human occupation. What has changed, however, is the human philosophy towards fire and its role in shaping the world around us. Indeed, it has only been recently that land and resource management agencies in the western United States have come to recognize the role of fire in the evolution and maintenance of natural ecosytems, as well as the eventual consequences of fire suppression on land and life. With this recognition has come a renewed interest of returning fire to the landscape, both to reduce excessive fuel loads that have accumulated as a result of decades of fire suppression, as well as improving the health of those natural communities that are fire adapted and dependent. Among many Federal and state agencies, this is manifest as the application of prescribed and controlled burns to achieve the results desired. After a relatively slow period of growth, the frequency and extent of these undertakings has increased markedly over the past decade.

In the case of Federal agencies, this has created a need to assess the affects of fire on cultural resources under the National Historic Preservation Act (NHPA) Section 106 consultation process as described in 36 CFR 800. Unfortunately, and for a variety of reasons, the ability of cultural resources managers to adequately understand the potential affects of fire and develop a systematic approach to fire-related compliance has not kept pace with the exponential growth of the fire programs. Consequently, most fire-related compliance is done "on the fly," and affords little opportunity for introspection or evolution.

This is the first volume of a four-volume series that deals with cultural resources compliance for fire programs at three of the four National Park Service (NPS) units comprising the Northern California Subcluster—Lassen Volcanic National Park (LAVO), Lava Beds National Monument (LABE) and Whiskeytown National Recreation Area (WHIS)—between 1998 and 2000. Subsequent volumes present unit-specific data and recommendations (Volume II: LAVO, Volume III: LABE, Volume IV: WHIS). Volume I contains a history and review of NPS fire policy, a discussion of the role of fire in northern California and the units of the Northern California Subcluster, and an appraisal of the effects of fire on cultural resources. This is intended to set the stage for the unit-specific treatments, reduce redundancy, and lend justification to the recommendations found at the end of each of the subsequent volumes.

BRIEF OVERVIEW OF NPS FIRE POLICY

With its inception in 1916, the NPS fire policy was one of full suppression of all wildland fires. Suppression remained the focus until 1968, and was followed by an emphasis on the broader concept of fire *management*. Driving this philosophical revolution was the appearance of the Leopold Report in 1963, in which fire was identified as a major component of ecosystem management. The NPS prescribed fire program began at Sequoia and Kings Canyon National Parks in 1968, with the earliest burning conducted under a "maintenance of habitat" rubric.

The transformation from fire suppression to fire management was made official policy in 1972 with the appearance of NPS 18. Catastrophic wildfires in Yellowstone National Park in 1988 resulted in policy refinements and new fire management plans, but also reaffirmed the stated policy. In 1994, the deaths of multiple wildland firefighters resulted in a policy shift towards fire use as a means of enhancing firefighter safety and resource protection.

A Federal Wildland Fire Management Policy and Program Review was developed in 1995, and signed by the Secretaries of Interior and Agriculture. Among the key points of this policy included:

- Protection of human life is the first priority
- Property and resources are the second priority
- Wildland fire must be reintroduced to ecosytems, across agency boundaries, and using the best available science
- Every area with burnable vegetation will have a Fire Management Plan (FMP).
- Education is a critical component, with audiences including agency staff, public, media, professional contacts, and other agencies

Furthermore, Congress provided for fire operations funds to cover prescribed fire and wildland fires that achieved resource benefits, as well as suppression. Prescribed fires are defined as those ignited by managers, whereas wildland fires derive from human or natural ignition sources. Wildland fires with a natural ignition source can be suppressed or allowed to burn for resource benefits, while human-caused fire will always be suppressed.

The new Wildland Fire Policy is considered a blend of safety, economics, ecology, and appropriate management actions. This blend is described in the fire management plan for each area. Equally important, the new policy is clearly *not*:

- A let-burn policy
- A safety risk to firefighters or the public
- Intended to only make “black acres”
- Independent of other programs and laws
- An impetus for a massive increase in prescribed fire activity

At the NPS level, Director’s Order (DO) 18, the replacement of NPS 18, was approved in 1998, and also identifies firefighter and public safety as the top priorities, provides allowances for natural fires to achieve resource benefits in areas where an approved fire management plan exists, and pledges to maintain the highest technical and professional expertise. Regional NPS fire management staff were delegated greater funding authority (up to $300,000) for implementation of prescribed fire projects and Burned Area Emergency Rehabilitation (BAER). A companion document, Reference Manual (RM) 18, was also issued in order to identify the implementation procedures for DO 18. At the core of RM 18 is the FMP, which offers a point of contact between fire management, and natural and cultural resources management. The essential components of an FMP are presented in Table ??. Following DO 18, all NPS FMPs, including those of the Northern California Subcluster, are currently being revised or have already been reworked.

A key sticking point with the 1995 Wildland Fire Policy is an objective and quantifiable measure of “resource benefits” that will be accomplished by wildland fire. At this juncture, biological benefits have been emphasized virtually to the exclusion of cultural and other considerations. The principle culprits for this discrepancy are probably an absence of clear cultural resources management objectives (both fire and non-fire related), as well as an incomplete understanding of the effects of fire on cultural resources.

Extreme wildfire behavior during 2000 led to another notable revision of fire policy in 2001. Multi-agency review of the 1995 Wildland Fire Policy led to the following principal conclusions:

- The 1995 Wildland Fire Policy is still generally sound and appropriate
- As a result of fire exclusion, the condition of fire-adapted ecosystems continues to deteriorate; the fire hazard situation in these areas is worse than previously understood

- The fire hazard situation in the Wildland Urban Interface is more complex and extensive than understood in 1995
- Changes and additions to the 1995 Wildland Fire Policy are needed to address important issues of ecosystem sustainability, science, education, communication, and to provide for adequate program evaluation
- Implementation of the 1995 Wildland Fire Policy has been incomplete, particularly in the quality of planning and in interagency and interdisciplinary matters
- Emphasis on program management, implementation, oversight, leadership, and evaluation at senior levels of all federal agencies is critical for successful implementation of the 2001 Wildland Fire Policy

Out of this evaluation, a number of implementation actions were identified including issues of fire management and ecosystem sustainability, response to wildland fire, wildland-urban interface, planning, science, workforce and organization, funding, communication and education, program management and coordination, and evaluation. Recognizing that funding shortfalls were a major impediment to the achievement of certain objectives in the 1995 Wildland Fire Policy, Congress obligated additional money in 2001 to increase staffing and implement important programs. Notable among the latter is the Wildland-Urban Interface Initiative, which provides funds to ????. WHIS, the only unit in the study with significant Wildland-Urban Interface issues in this study, has proposed to ???. All three units have recognized an increase in the number of permanent and seasonal fire personnel, ranging from firefighters to fire ecologists and archeologists.

For better or worse, wildland fire in the western United States has become a political lightening rod, the popularity of which seems to vary in direct proportion with the severity of the current or most recent fire season. In general, big fire years will translate into big dollars for fire management programs, though often in the short-term. The logic of this knee-jerk reaction is diminished when one acknowledges that proper wildland fire management demands a polythetic approach and long-term commitment to be successful. Only time will tell whether or not the current policies are truly viable.

CHAPTER 2
FIRE AS A NATURAL AND CULTURAL PROCESS IN NORTHERN CALIFORNIA

Holocene paleoecological data gathered from a variety of contexts in northern California reflect the pervasiveness of wildland fire in both time and space (e.g., Woolfenden 1996; Spaulding 1999). The reasons for this have generally been attributed to a drier climatic regime, and concomitant vegetation shifts, as well as the probable arrival of humans in the Americas at about 12,000 B.P. The Mediterranean climate characteristic of much of northern California is ideal for promoting annual fire activity, and the presence of vegetation mosaics at a variety of spatial scales testifies to the historic role of wildland fire in this region. Furthermore, a number of species and communities exhibit fire-adapted traits, some of which are summarized in Table ??. Fire histories, as recorded in fire scars and other data, indicate that fire consistently occurred at intervals of less than 50 years in nearly all northern California vegetation communities, and less than 20 years in mixed conifer forests, oak woodlands and grasslands (McKelvey et al. 1996:1033; Skinner ????; Arno 2000; Paysen et al. 2000).

Fire regimes are the general characteristics of fire found in a given area, and vary by vegetation and landscape (Brown 2000). Fire regimes can be profitably classified in terms of frequency, rotation, spatial extent, magnitude and seasonality (Skinner and Chang 1996:1043):

- *Frequency* refers to how often fire occurs within a given time interval, and is usually expressed as a Fire Return Interval (FRI), or the amount of time between each fire.
- *Rotation* is the amount of time required to burn an extent equal to the area of interest. For example, if a 100,000 ac. area burns in 100 years, the fire rotation is 100 years.
- *Spatial extent* is the size of a fire and the spatial patterns created.
- *Magnitude* encompasses both fire severity and intensity. Severity refers to the changes in the ecosystem caused by a fire, and can be characterized quantitatively or qualitatively (Table ??, Fig. ??). Intensity is the amount of energy released by a fire.
- *Seasonality* is the timing of a burn, and relates to fuel moisture, phrenology of the vegetation, and resultant fire effects. Vegetation within a given ecosystem is reflective of the seasonality of fire activity.

Chang (1996:1071-1073) provided a simplified classification of the various types of fire regimes (Table ??), all of which probably occurred to a greater or lesser extent in the units of the Northern California Subcluster. Fire regimes and their implications for cultural resources are discussed in greater detail below.

It is important to recognize that fire regimes have changed in the distant and recent past and continue to do so, although there is debate over why this is the case (Chang 1996:1072-1073). Climate has long been recognized as a catalyst for such shifts; for example, Swetnam (1993) found that drought conditions of the Medieval Climatic Anomaly between ca. 1000 to 700 B.P. promoted a higher fire frequency in Giant Sequoia groves than the more moist periods before and after, and that the spatial extent of those fires was reduced as well. In the absence of the interventions discussed below, the warm and moist climatic conditions of the past 150 years compared to those of the last several centuries almost surely would have promoted a variety of complex responses in regional ecosystems, and induced shifts in fire regimes (Skinner and Chang 1996:1060). Still, human occupants, both native and non-native, have also played a role in shaping and maintaining fire regimes in northern California.

Wildland Fire and Humans in Northern California

Intro

Native Americans and Fire

A seminal monograph by Lewis (1973, 1993) set the stage for an appreciation of the role Native Americans played on structuring the composition and distribution of resources in California through the use of fire. Since then, the topic has received a great deal of attention throughout western North America, and California and the Pacific Northwest in particular (e.g., Roper-Wickstrom 1987; Lewis 1989; Blackburn and Anderson 1993; Keter 1995; Anderson 1996; Anderson and Moratto 1996; Anderson et al. 1997; Boyd 1999). Fire was used for a variety of tasks, including increasing the yields of economically important vegetation like food stuffs and basketry materials, driving game, reducing the chance of catastrophic wildfire, maintaining an open landscape, and improving the flow in springs and streams by thinning riparian vegetation.

However, researchers have questioned the contribution of Native American fire to the cumulative annual acreage burned (Roper-Wickstrom 1987:1-4), and it has proven difficult for resource managers to integrate Native American and "natural" fire regimes. Keeley and Stephenson (2000:259) summarized the various arguments for and against the inclusion of Native American burning patterns with those that occurred naturally (Table ??). Unfortunately, it is difficult to assess the need whether or not to include Native American burning practices when we have yet to figure out what the nature of those practices were in either a literal or figurative sense. This is significant because the major planning documents associated with each of the NPS units in this study explicitly or implicitly identifies a desire to return to pre-European fire regimes (Table ??).

When considering the role of Native American burning on past landscapes in northern California, it is important to first acknowledge that fire was simply one tool in an arsenal of resource management tactics, and that its use was probably dictated by a wide variety of contextual issues. Native Californians faced an array of resources management decisions related to fire within a given day, season, or year, some of which were contradictory. For example, fires set to increase browse for deer or improve the health of important basketry materials also had the potential to destroy seed crops or firewood supplies. As such, it seems clear that Native Americans did not indiscriminately apply fire to the landscape in either time or space.

The most profitable way to understand hunter-gatherers in northern California and the aboriginal use of fire as a management tool is to consider them in the context of hunter-gatherer subsistence-settlement patterns. Drawing from ethnographic analogies developed from the study of recent hunter-gatherers and other organisms, central place theory and the refuging system of resource acquisition offer a useful conceptual framework from which to evaluate this issue. Central place theory is based on the notion that the distance between energy consumers and energy sources is related to transportation costs (Hamilton and Watt 1970). The distribution of organisms across the landscape and the size and configuration of group boundaries is a function of an attempt to reduce locomotion/transportation costs between energy consumers and energy sources.

The refuging system of resource acquisition is the rhythmical dispersal of groups of members of a population away from and returning to a fixed point in space (Hamilton and Watt 1970). At historic contact, Native Americans in northern California clearly practiced the dispersal of group members from a fixed point (e.g., a village) in order to extract various resources such as grass seeds, acorns, and salmon, a considerable quantity of which were transported back to the aforementioned fixed point for later consumption. At LABE, for example, the Modoc resided in permanent lakeside villages during the winter months, relying upon dried game and plants. In the spring, summer, and fall, various groups emanated from the winter village to extract fish, game, ripening plants, and other resources at seasonal camps (Ray 1963).

Binford (1980) described groups practicing such strategies as "collectors." Collector strategies tended to evolve in regions characterized by seasonal and spatial resource imbalances, and include a heavy reliance on food storage, high degree of logistical organization, curated technologies, and bulk patterns of resource extraction.[1] Collectors utilize residential bases (places from which task groups depart to obtain food and other resources and subsequently return), field camps (base camps for task groups), locations (places of resource extraction, e.g., kill and butchering sites), caches (for resources and equipment), and stations (places where information is gathered on resources).

Figure ?? depicts the relevant components of central place theory and refuging systems. The *core* (read residential base and/or base camp) is the central place location of the population. The core generally contains maintenance structures (e.g., houses), energy stores (e.g., food, firewood), and processing tools. *Arena of resource acquisition* refers to the total area of resource acquisition for the population in an annual cycle (catchment area following Vita-Finzi and Higgs 1970). The *biodeterioration zone* results from the overexploitation of resources within the arena of acquisition. The *trampling zone* is an unproductive resource zone that results from trampling and pathway effects.

A similar model can be created using the settlement system nomenclature introduced above (Fig. ??). In this example, the *residential base* is the equivalent of the core in the above model. The *extended range* refers to that area monitored for resource abundance and distribution, and might comprise the catchment area. The *campground zone* is the area immediately surrounding the residential base that typically yields firewood, water, basketry materials, medicinal plants, etc., but food resources are typically scarce owing to excessive utilization. The campground zone encompasses, at least in part, the previously defined biodeterioration zone. The *foraging zone* is that area surrounding the campground zone that is traversed by task groups who return to the residential base each night. Locations representing plant, animal and other resource extraction occur in the foraging zone. Beyond the foraging zone is the *logistical zone*, the area where task groups spend one or more nights away from the base camp. Sites found in the logistical zone include field camps, locations, stations, and caches. In reference to the refuging model above, most sites in the foraging and logistical zones should occur within the trampling zone.

Obviously, the size and configuration of these components, which are presented in idealized form, is a function of the population, types and distributions of resources, topography, travel routes and other factors. Likewise, the boundaries between them can be muddled or quite distinctive. The nature of adjacent populations also deserves consideration. As depicted in Figure ??, resource availability profiles for a given arena of resource acquisition/extended range should vary based on population size and/or inter-residence distance. Consistently, however, we see that resource abundance is lowest at the core/residential bases, rises with increased distance from this point, and peaks at the boundaries between adjacent arenas of resource acquisition/extended ranges. This means that competition for key resources between adjacent groups was likely to occur at these boundaries.

Ironically, the notion of immutable boundaries was not well developed among most native northern Californians, and accounts of territorial overlaps and intergroup resource access and sharing occur in the ethnographic record (SOURCE). Dyson-Hudson and Smith (1978) suggested that territoriality should arise in cases where resources are both dense and predictable. In California, resources like acorns and anadramous fish fit this description quite well, and some have suggested that the high human population density and linguistic diversity found in northern California at historic contact was a <<Territoriality>>. Intensification

In a cross-cultural analysis of fire use by hunter-gatherers worldwide, Lewis (1993; Lewis and Ferguson 1999) identified several common threads that may prove useful for the present study. Lewis recognized *fire yards*, openings or clearings with a forested area that are maintained by burning, and *fire corridors*, the fringes of ridges, trails and other linear features that are similarly maintained by fire. The firing of these areas, in combination with other anthropogenic and natural fire, created a *fire mosaic*, vegetation stands of various ages and successional stages created by fire, and interspersed with recently burned areas. While Lewis and Ferguson (1999:167-168) suggested that the creation of fire yards was principally a phenomenon associated with densely forested habitats like those found in northwestern California, the concept can also be used more inclusively. For example, while fire was probably a pervasive and widespread phenomenon at LABE, LAVO, and WHIS (see below), Native Americans would have burned different areas at a various intervals, intensities and seasons. For example, productive oak groves, patches of basketry materials, tobacco, and other important understory plant resources, the margins of villages, and clearings in fields of chaparral are frequently mentioned as having been intentionally burned by Native Americans in ethnohistorical and ethnographic sources (e.g., Anderson 1993; Lewis 1993; McCarthy 1993; Anderson and Morrato 1996; Boyd 1999; LaLande and Pullen 1999; Lewis and Ferguson 1999). Fire was probably purposefully excluded, altogether or at certain times, from select areas like basketry material patches, firewood sources (King 1993), seed patches, and habitation sites. For example, the ethnographic record contains frequent mention that hazel shoots were collected two years after a hazel plant or patch was burned (SOURCE), with the implication that such areas were not burned after the first year, or burned at such an intensity that would not harm growing shoots.

Fire Followers

Seasonality

The skeptical reader still might question how in an open, xeric landscape like the volcanic tablelands of LABE, the concepts of fire yards and fire corridors can be logically applied. Lewis and Ferguson (1999:172) documented that fire corridors are maintained by Aborigines in the desert areas of northern Australia, and archeological evidence suggests that Native American travel routes at LABE may have been conditioned by geological phenomenon like lava flows, and it is possible that fire was employed along these corridors. The fire yards of the LABE region were probably subtle compared to those of forested areas, but may have contained important plant resources utilized for human consumption or raw materials, or were improved through burning to influence the distribution of ungulates and other animals with the intent of optimizing the location and productivity of hunting areas.

The concepts of fire yards, fire corridors, and fire mosaics can be considered in regard to the refuging model presented above. Figure ?? depicts a hypothetical distribution of fire yards linked by fire corridors principally within the biodeterioration and trampling zones of a particular arena of resource acquisition for a given village. Through a combination of “fire-proofing” the village site and other important resources like firewood supplies and patches of basketry materials, larger anthropogenically burned areas are found in close proximity to the core. Various fire yards in the trampling zone are linked by fire corridors. Beyond the trampling zone, fire results from natural ignitions and human-caused blazes that spread beyond the trampling zone (this could be unintentional or intentional, e.g., generalized burning to create an open landscape). Admittedly, this conceptualization creates an overly simplistic and narrow view of Native American land-use and firing practices, and the author acknowledges that the situation becomes far more complex when time-depth is considered for a single arena of resource acquisition (Fig. ??), and when viewed at a regional level (Fig. ??). Still, based on various historical and ethnographic accounts and recent work with contemporary Native American groups, this application probably has some degree of validity.

This hypothesis also has implications relative to the development and maintenance of exclusive group territories. As noted above, resource abundance peaks at the boundaries between organisms or groups of organisms (cf. Fig. ??). Humans are unique in their ability to manipulate the environment to increase and optimally position important resources. For example, research has documented that under the proper conditions, wildlife habitat, and consequently populations, could be improved and inflated through the use of fire (see Smith 2000), and the same can certainly be said of plant resources. As such, anthropogenic fire had the potential to be employed as a tool to shape or at least influence the distribution, abundance and habits of important resources, with the implication that resources (fauna in particular) could be drawn away from contested boundaries, and closer to core areas (Fig. ??), thereby improving foraging predictability and efficiency, and reducing risk. Likewise, the intentional exclusion of fire from certain areas, like the margins of fire yards and perhaps at group boundaries, would have only enhanced this predictability. As regional populations increased and residential mobility and territorial size decreased, anthropogenic fire probably served as an important means of facilitating resource intensification. LaLande and Pullen (1999:266) suggested that intentional burning could have actually fostered a human dependence upon localized areas, prompting a decrease in mobility and heightened sense of territoriality, and that burned areas may have actually served as ethnic territorial markers.

Gender based fire

To date, few studies have attempted to demonstrate that Native American fire use was of a sufficient scale and extent to still be recognizable, although some compelling evidence has been found. For example, Barrett and Arno (1999) found that FRI were significantly shorter between 1500 and 1860 in 10 forest stands located adjacent to grasslands compared to 10 more remote forest stands found in nearby canyons in the northern Rockies. Because the former localities were utilized more heavily by Native Americans, Barrett and Arno (1999) suggested that anthropogenic fire was the primary reason for the difference. Anderson and Carpenter (1991) documented a major shift in the vegetation of Yosemite Valley at about 650 B.P., which also coincided with Native American settlement pattern change. The pre-650 B.P. vegetation in the Valley was dominated by ponderosa pine, white fir, incense cedar, and Douglas fir, while an open canopy forest with oaks, sage and shrubs was more prevalent in post-650 B.P. contexts, along with elevated charcoal concentrations in sediment samples. Climate change was not sufficient to explain this shift. Native American settlement in Yosemite Valley appeared to have intensified at about this time, as did the emphasis upon acorns as a staple food. The ethnographic inhabitants of Yosemite Valley were noted to have burned the area on a regular basis to kill larger conifers and prevent encroachment of smaller ones. Presumably, this action would have caused the expansion and maintenance of oak woodlands at the expense of shade-tolerant species like firs and incense cedar.

The issue of Native American fire use is clearly worthy of greater attention and has many implications for the effectiveness of the prescribed burn programs at the units in this study and elsewhere. Plants and animals, from individual organisms to communities, have evolved in concert with human intervention for at least 12,000 years, and it would a major misconception to assume that simply reintroducing fire to an area from which it has been excluded is somehow replicating Native American firing practices because we know that Native Americans used fire. Indeed, as the discussion above hopefully demonstrates, Native American fire use was both extremely sophisticated and dictated by a variety of contextual issues.

Non-Natives and Fire

Beginning at about 1850, a profound change in northern California fire regimes took place, and this shift is part of a trend that continues today (Skinner and Chang 1996). Prior to the 1900s, most fires in northern California were surface fires of low to moderate severity with patches of higher severity, and crown fires and extensive mortality were rare. Wildland fires often burned for weeks or several months, and under a variety of weather conditions. These fire regimes produced spatial patterns that were variable over the landscape. After 1900, a trend towards large fires with high mortality and continuous effect over the landscape emerged, with the greatest changes affected in locations were fire was most common in the past such as ponderosa pine, black oak and mixed conifer stands. Low severity surface fires became the exception rather than the rule. Skinner and Chang (1996:1060) suggested that the rapidity of change in twentieth century fire regimes appears to have no analog in the recent past, but the reason or reasons for these changes are a matter of debate.

Along with a warm and moist climate, Skinner and Chang (1996:1057) attributed the transformation to a variety of historical factors. First, Native American populations declined markedly during and immediately following the Gold Rush due to disease and genocide. Second, landscape alterations brought about by mining resulted in significant vegetation shifts conducive to severe fire behavior (e.g., more extensive brush fields). Third, extraction of wood material resulted in the accumulation of residues that supported severe fires. Fourth, increased stock grazing had the duel effect of reducing fine fuels, and the indiscriminant application of fire in an attempt to improve forage. Finally, Federal fire exclusion policies enacted in the early 1900s promoted a highly successful suppression ethic that continues to this day. Records clearly indicate a decline in the number and acres of human-caused fires through the twentieth century.

FIRE REGIMES AT LAVO, LABE AND WHIS

The following is a review of probable fire regimes that exist and/or existed at LABE, LAVO, and WHIS. These data have implications for past human land-use, and therefore the archeological records at each unit, as well as expectations regarding potential fire effects on archeological resources.

LABE Fire Regimes

A detailed fire history study has yet to be conducted at LABE, but the issue was addressed in preliminary form by Johnson and Smathers (1974). Using photographs taken during the Modoc War of 1872-1873 and other historical documentation, Johnson and Smathers (1974) outlined proposed vegetation changes that had occurred at LABE as a result of fire exclusion and suppression. At historic contact, three principle vegetation communities existed within LABE: grassland, woodland, and coniferous forest (Fig. ??). Of these, the coniferous forest, comprised of an overstory of ponderosa pine (*Pinus ponderosa*), white fir (*Abies concolor*), and incense cedar (*Calocedrus decurrens*), was identified as having undergone the least amount of change. Still, while formerly park-like in appearance, the post-suppression coniferous forest contains significant understory vegetation comprised primarily of mountain mahogany (*Cercocarpus ledifolius*) and antelope bitterbrush (*Purshia tridentata*).

The woodland community, which lay between the coniferous forest and grassland communities, was characterized by an association of ponderosa pine and western juniper (*Juniperus occidentalis*). Understory vegetation, primarily mountain mahogany and antelope bitterbrush, was likely relegated to volcanic outcrops or locations with light and discontinuous fuels. Ponderosa pine was largely eliminated from this community by drought and insects in the 1920s, and today the association includes western juniper and chaparral species.

The grassland community, which was extensively photographed during the Modoc War, was comprised of a bunchgrass-sagebrush association in pre-suppression times. Dominant species included sagebrush

(*Artemisia tridentata*) and bluebunch-wheatgrass (????). Overgrazing resulted in the replacement of bunchgrass by native and exotic dominant grasses (e.g., cheat grass [*Bromus tectorum*]), while fire suppression encouraged the spread of western juniper and an increase in the percent cover of sagebrush. A study proposed to investigate the status of western juniper at LABE (SOURCE) was recently funded, and should provide valuable information on the proposed encroachment of this species.

As of 1974, Johnson and Smathers (1974:112) documented 75 lightening-caused fires at the Monument within the previous 41 years. Sixty-four percent of these fires had occurred in the grassland community (one fire per 0.86 years), 27% within the woodland community (one fire per 2.1 years), and nine percent in the coniferous forest (one fire per 5.8 years). Johnson and Smathers (1974:113) speculated that the development of three distinct vegetation communities may have resulted from differences in fire frequency in different areas of the Monument. Recent studies conducted in similar vegetation communities provide additional expectations regarding past fire regimes at LABE. These attest to the common occurrence of fire within these communities (Table ??).

Native American fire use in the LABE region is poorly understood. MORE

Some predictions can be derived based on historical Native American land use and the archeological record in the LABE region (see Volume II for additional details). Permanent and semi-permanent villages along the shore of Tule Lake were probably protected from the effects of uncontrolled conflagrations by the application of fire along their margins. Likewise, fire yards and corridors were probably maintained within easy walking distance of these villages and from which grass seeds, <<more>>, and to improve forage for ungulates and other game. Recent survey conducted on top of Gillem Bluff west of the lakeshore revealed a large amount of flaked stone tools and debitage consistent with hunting paraphenalia. This area, within easy walking distance of the lakeside villages, was probably utilized by foraging and logistical parties in search of ungulates, and it may have been burned at a relatively frequent intervals. The encroachment of western juniper that is occurring today may well have been held in check by the high frequency of anthropogenic fire.

More than two dozen ice caves located in the southern half of the Monument were a focal point of settlement in prehistoric times, although the archeological records associated with those that have been surveyed range from well developed middens to relatively sparse lithic scatters. Virtually all ice caves are found in the grassland and woodland communities. These areas were probably visited primarily on a seasonal basis, between the spring and fall. As virtually the only viable water sources away from the lakeshore, it stands to reason that fire yards were created in close proximity to these areas in order to ensure the presence of desirable resources.

Away from the ice caves in the LABE interior, the archeological record is characterized primarily by small lithic scatters. These presumably reflect seasonal hunting endeavors, as well as the reduction of bifaces and blanks of obsidian procured from the Medicine Lake Highlands. The sites occur in grassland, woodland, and coniferous forest communities. Burning conducted in association with such sites is uncertain, but some may be found along travel routes that probably linked lakeside villages with the LABE interior and points beyond. The locations of these travel routes may have been conditioned in part by the presence of rough lava flows. Perhaps these corridors were also burned out on occasion.

LAVO Fire Regimes

Although an all-encompassing fire history is not available for LAVO at this time, some limited scale studies have been conducted within the park, and data are available for the northern Sierra Nevada and southern Cascade Range. Veg Communities

Taylor (2000) recently presented the results of a study conducted on Prospect Peak in the northeastern portion of the park. Four vegetation types were identified: lodgepole pine forest (LP) on mesic flats at the base of the peak, jeffrey pine (JP) and jeffrey/white fir (JP/WF) at mid elevations, and red fir/western white pine (RF/WWP) at higher elevations. Wildland fires occurring between 1507 and 1937 were documented. Of these, 19 occurred in RF/WWP between 1685 and 1937; 45 in JP/WF between 1546 to 1903; 46 between 1507 and 1932 in JP; and 12 in LP (no dates obtained). In terms of seasonality, wildland fires occurred during the growing season (mid- May to late August) in the lower elevation JP and JP/WF forests occurred more frequently than in RF/WWP forest. This was probably attributable to the fact that fuels in lower elevation forests dry earlier in the season and are capable of carrying fire, whereas those in the upper montane zone cannot support fire until late fall or early summer.

Pre-suppression fire return intervals were found to vary by vegetation type, with 4 years for JP, 5 years for JP-WF, and about 10 years for RF-WWP. This pattern was also found to hold for large fires, with means of 6, 10 and 27 years in the JP, JP/WF, and RF/WWP communities, respectively. The differences probably stem from variations in factors that influence flammability. First, rates of fine fuel production are more rapid in lower elevation forests so fire is able to return more quickly; second, fuels at lower elevations are dry enough to burn for a longer period each summer; and third, surface fire intensity is higher in low density fuel beds characteristic of Jeffrey pine forest than high density beds characteristic of red fir forest, with the implication that lower elevation trees are more likely to be scarred by fire.

When analyzed by slope, mean fire return interval was shorter on east (6 years) and south (11 years) than west (22 years) facing slopes, and the pattern is repeated for larger burns (east=9 years, south=11 years, west=27 years). In terms of forest type, the median fire return interval is shorter in JP and JP-WF forests on east and south facing slopes than those oriented to the west. This was attributed largely to local conditions such as the distribution of lava flows.

In pre-suppression times (1627-1904), mean fire area was about 1,130 ac., with a median of 905 ac. Eight fires larger than about 1,975 ac. were documented. Broken down by forest type, JP supported the largest fires (mean=595, median=905 ac., range=96 to 1,833 ac.), followed by JP/WF (mean=482, median=413, range=15 to 1,646 ac.) and RF/WWP (mean=435, median=319, range=27 to 1,811 ac.). Finally, the fire rotation is much shorter in JP (24.5 years) and JP/WF (31.3 years) than RF-WWP (75.9 years).

Like elsewhere in montane California, fire occurrence declined dramatically on Prospect Peak after 1905 as a result of Federal land management policy. Among the changes documented in the forest of Prospect Peak include increased density and forest floor fuels, disappearance of some shrubs, and the invasion of white fir in areas with a Jeffery pine overstory. Given the size of pre-suppression wildland fires, it was recommended that NPS staff implement larger prescribed burns in order to mimic pre-suppression conditions and restore fire effects.

MORE

The prehistoric archeological record at LAVO occurs at three principal locations, including Warner Valley in the south-central portion, Sulfur Creek drainage in the southwestern quarter, and Manzanita Lake in the northwestern corner of the Park (White 2000; see Volume III for additional details). Scattered sites also occur on the margins of lakes and meadows throughout LAVO. It remains to be determined whether the distribution mirrors reality or if the archeological record has been compromised by extensive Holocene volcanic activity. Assuming the former, and in conjunction with presumed historic Native American land use patterns (i.e., seasonal occupation, special use), some assumptions regarding anthropogenic burning can be put forth.

Seasonal village sites occur in the Warner Valley area, Sulfur Creek drainage, and perhaps Manzanita Lake. Burning in these areas was presumably fairly complex, and focused on the creation and maintenance of fire yards. MORE

WHIS Fire Regimes

Vegetation at WHIS can be segregated into six relatively discrete communities, including mixed chaparral, ponderosa pine/mixed conifer forest, riparian, blue oak grassland, black oak woodland, and knobcone pine forest (Fig. ??). Each of these communities exhibits a close relationship with wildland fire (Table ??).

Gibson (1999) recently evaluated the historical and ecological role of fire at WHIS. Considering pre-European settlement fire regimes at WHIS, Gibson (1999:1-2) postulated, based on data from similar contexts, that lighting was the principle source of natural wildland fire ignitions within the unit. Between 1969 and 1998, 25 lightening caused fires had been documented at WHIS (slightly fewer than one per year), and most of those occurred in lower elevations (1,500 to 2,500 ft.), in the upper one-third of slopes ranging from 26 to 40% with northern and eastern aspects.

Following permanent Euroamerican settlement in the area at around 1850, wildland fire remained an integral aspect of the region, albeit not always a positive one. For example, <<MORE>>.

Early photographs and paintings are also useful for establishing vegetation conditions as they appeared in the 1800s. Figures ?? and ?? depict the Tower House complex in the 1850s or 1860s. Of interest is the vegetation on the ridges to the south of the complex. Shown are what appear to be sparse, fairly widely spaced conifers and oaks, along with mixed age chaparral. Today, this same area, after years of fire suppression, contains seral stage oak woodland and chaparral communities. While logging may have contributed to the conditions in the historical scenes, it is likely that the proximity of that time to an era of active Native American burning and absence of fire suppression contributed as well.

More quantitative data are available regarding twentieth century wildland fire activity within WHIS (Gibson 1999:3). Since 1929, wildland fires less that 100 ac. in extent have occurred on an average of every 4.5 years, and 1,000 to 5,000 ac. wildland fires every 13.75 years on average. Since 1969, more than 7,000 ac. within the Unit have burned, almost half of which (44%) has been due to wildland fires ignited by lightening strikes.

Proxy data regarding the pre-European fire regime at WHIS can be derived by consulting studies conducted elsewhere on the major habitats comprising the unit: ponderosa pine-mixed conifer, black oak, and whiteleaf manzanita-shrub (Gibson 1999:3-4). The north-facing slopes at WHIS are comprised primarily of ponderosa pine-mixed conifer forests, with some black oak woodland. Such forests have an intrinsic relationship with wildland fire (Arno 2000:100-101). A fire scar analysis conducted with ponderosa pines on Shasta Bally indicated that prior to 1900, the fire return interval was about 13.5 years (Johnson 1980 cited in Gibson 1999:4). When analyzed by aspect, fire occurred more frequently on south-facing slopes (12.9 years) than southeast (13.3 years) or northeast (16.2 years) slopes. Based on fire scar data from a 186 year-old ponderosa pine in the Coggins IV Prescribed Burn Unit, Gibson (1999:4) determined the median pre-suppression fire frequency to be 12.0 years, while that figure increased to 41.0 years in post-suppression times. Fire histories obtained from ponderosa pine-mixed conifer forests in other portions of the western United States are consistent with the WHIS data, including a median fire return interval of 7 to 15 years (range of 5 to 33 years) in the nearby Klamath

Mountains (Gibson 1999:4). Black oak woodlands occur most frequently on north-facing slopes within the unit, while the largest and most decadent stands of chaparral occur on the south facing slopes (Gibson 1999:4). A high percentage of these stands have no historical record of fire, indicating ages in excess of 70 years.

In terms of Native American fire use within WHIS, Gibson (1999:2) acknowledged the paucity of published data for the Wintu as a whole, let alone for the unit itself. However, a recently completed *Ethnographic Overview and Traditional Use Study* demonstrated that contemporary Wintu have interest in gathering certain plant species within WHIS (Emberson 2000:55), and that fire is a means of maintaining the health of those populations in other locales. Communications between this author and a Wintu elder (Willard Rhoades) elicited some information on the past and contemporary use of fire by the Wintu. While the extent and purpose of Native American burning within WHIS are uncertain, ethnographic analogy from similar areas, along with the striking patchiness of the vegetation (Gibson 1999:2), strongly suggests that Native American-induced fires were a component of the overall pre-European fire regime.

CHAPTER 3
FIRE EFFECTS ON ARCHEOLOGICAL RESOURCES: AN OVERVIEW

It has not been until recently that cultural resource managers have taken an earnest approach to understanding the effects of fire on archeological resources. Still low-level experiments and post-burn observations relating to the effects of fire on artifacts have been performed since the 1960s (Kelly n.d.), although a lack of control and comparability have rendered the results of many of these studies impractical for many applications. The impending publication of the *Rainbow Series* on the effects of fire on archeological resources (Source) will provide much needed clarity and guidance on the subject. Without access to the above volume, the following discussion of fire effects is necessarily broad, and heavily slanted towards those conditions found in the easternmost units of the Northern California Subcluster.

DIRECT, OPERATIONAL AND INDIRECT EFFECTS

The effects of fire on cultural resources can be conveniently divided into direct, operational and indirect categories. Direct effects are those where the fire itself is the cause of the impacts, operational effects occur as a result of associated operations like line construction or staging, while indirect effects are ones where fire and/or associated operations result in changes to local context such that resources will be effected. Some examples of direct, operational and indirect effects common to the units of the Northern California Subcluster are presented in Table ??.

Direct Effects

Direct effects are probably the most troublesome, if not misunderstood, of the fire impacts to the cultural resources manager. This is due to the fact that, everything being equal, all archeological resources within a given burn unit have the potential to be exposed to fire, and that our understanding of the effects of fire on stone, metal, bone, wood and other common materials is not yet satisfactory.

Basic Fire Concepts

Before engaging in a full discussion of direct effects, it is necessary to first present some basic fire concepts (adapted from Ryan and Noste 1985; Ryan n.d.). Fire behavior is driven by fuel (the source of energy that does the work of change, such as altering the ecosytem or attributes of an artifact), and can be segregated into total above ground biomass, total fuel, and available fuel. The amount of total above ground biomass typically exceeds total fuel, and there is more total fuel than available fuel (Fig. ??). Furthermore, the amount of above ground biomass varies by vegetation type; more is potentially fuel in shrublands than forests (where much of the biomass is contained in greenwood), and more still in grasslands.

Energy is another critical component of fire. Total energy is the product of available fuel and heat content, while total energy results from a combination of the energy release and duration. The energy release rate and duration of burning determine the amount of heat created. Burn rates are conditioned by the physical configuration of the fuels. For example, cylindrical fuels like grasses, conifer needles, twigs and logs burn at a relatively uniform rate of about 3.15 min./cm. diameter. As such fine fuels like grasses and needles release energy quite quickly (order of seconds). By contrast, partially decomposed materials like duff and rotten logs tend to burn much more slowly, and the rate is more variable but generally longer (order of hours).

Fuels can be divided into ground, surface and aerial categories. Ground fuels include duff, decomposing logs and roots. Surface fuels are less than about 2 m. high such as grasses, forbs, litter, low shrubs and seedlings. Finally, aerial fuels are taller than 2 m. and comprise tall shrubs, trees and snags.

Fires tend to burn in a complex manner depending on fuels, weather and terrain. It is the behavior of a fire, including the heat transfer mechanism and proximity to an archeological resource that will determine the amount of damage that is done. While both fire behavior and heat transfer mechanisms are complex, it is possible to characterize fire behavior in at least general terms, including ground, surface and crown fires (Table ??).

Generally speaking, ground and creeping surface fires are the least intense, and along with, at least in some instances, active surface fires, are the preferred fire behavior for prescribed burns in the Northern California Subcluster. Running and crown fires are almost exclusively associated with wildfires. In reference to the fire severity classes presented in Table ??, ground and creeping surface fires typically fall into the low severity category, whereas active and running surface fires result in moderate severity, and crown fires in high severity. As noted above, most researchers believe that ground and surface wildland fires were the norm in pre-1900 northern California, while running surface and crown fires were far more rare.

In terms of potential impacts to archeological resources, important corollaries of fire behavior are heat transfer, fuel consumption and soil heating. Heat transfer refers to how energy gets from the combustion zone to adjacent objects like vegetation, archeological resources, etc. The four basic modes of heat transfer are radiation, convection, conduction, and mass transport (Table ??). In prescribed fire contexts, radiation, conduction, and, to a lesser extent, convection are the most common forms of heat transfer.

Fuel consumption is related to the interplay between the total and available fuel in an area. Vegetation size class and fuel moisture content are the are the principal factors influencing fuel consumption, with moisture content by far the most important. Fuel moisture content is expressed as the percent or fraction of oven dry weight of fuel. Fuel moisture is physiologically bound in living plants (generally 80 to 100%), although daily fluctuations can vary considerably within different species. Fuel moisture content decreases as plants mature. Fuel moisture in dead or dying vegetation fluctuates in concert with shifts in temperature, humidity and precipitation.

The temperatures reached a various depths of the soil profile during and after wildland fires are influenced by a variety of factors. First is the amount of energy received at the surface of the soil profile. While running surface and crown fires may generate a tremendous amount of energy, the effect will typically extend to only the upper 2 to 3 cm. of the mineral soil. Sustained ground fires in duff and deadfall, however, can result in a significant increase in soil temperature that extends below the duff/mineral soil interface. The depth to which soil will be heated is a function of soil moisture content and, to a lesser extent, soil texture (Figs. ??, ??, ??). Under wildfire conditions, soil temperatures to 200° C can be expected up to depths of 10 cm. or more below surface. Recent research in Giant Sequoia-mixed conifer forests of the southern Sierra Nevada indicated that prescribed burns also produce fairly high subsurface temperatures at shallow depths (Haase and Sackett 1998). Tree roots are another significant source of subsurface heating. <<MORE>>

A number of predictive computer modeling programs have been developed to assist land managers in devising burning prescriptions. The BEHAVE model is commonly utilized for fire planning in the NPS, <<MORE>>. An example of a BEHAVE ???? is depicted in Fig. ??. FOFEM (First Order Fire Effects Model) and CONSUME are useful for deriving predictions of duff and woody fuel consumption, and FOFEM can also be employed to predict temperatures of a soil profile under different burning conditions. <<MORE>>

Implications for Archeological Resources

The next obvious question is how to translate what we know about fire behavior into implications for direct impacts to the archeological record. It goes without saying that, all else being equal, the more severe the fire behavior, the greater the potential for adverse impacts to the archeological record. Of course, not all archeological materials are equally susceptible to the effects of fire (e.g., wood versus stone). This holds true even within single artifact classes. For example, in the case of obsidian tools and debitage, hydration rinds are more vulnerable to fire effects than the actual physical structure and integrity of the obsidian itself. Therefore, it is necessary to explore separately what is known of the effects of fire on the materials that commonly comprise the archeological resources of the Northern California Subcluster. How this information can be integrated with fire behavior data to devise common-sense approaches to fire-related compliance is explored in the next section.

Flaked Stone

Flaked stone artifacts in the Northern California Subcluster generally occur as formed tools and debitage. Common raw materials represented include obsidian, cryptocrystalline silicates, and basalt and other medium to coarse-grained igneous rocks. A number of studies throughout northern California have demonstrated the value of certain flaked stone tools as time-markers, projectile points in particular, for building local and regional chronologies (e.g., Sampson 1985; Basgall and Hildebrandt 1989; MORE). Likewise, debitage analyses can provide information about technology, adaptation, ethnicity, mobility and other matters.

Flaked stone tools and debitage of all raw materials are vulnerable to structural modifications (e.g., breakage, melting, discoloration, weight loss) as a result of heat from fire. Laboratory studies performed on cryptocrystalline silicate specimens revealed that beyond 350° C artifacts crack, spall, and shatter (Purdy and Brooks 1971; Mandeville 1973). A recent prescribed burn field experiment conducted in sagebrush resulted in breakage for all 90 cryptocrystalline silicate specimens, including some that shattered beyond recognition (Benson 1999). These artifacts were placed in light, moderate and heavy fuel contexts, and exposed to temperatures between about 100° and 1300° F.

It is well documented that certain cryptocrystalline silicates were preheated to improve flaking qualities (Purdy and Brooks 1971; Mandeville 1973; Collins and Fenwick 1974). Among the physical alterations to the raw materials that undergo heat treatment include potlidding, crazing, and color changes, and these can occur under wildfire and prescribed burn contexts as well (e.g., Romme et al. 1993; Lentz 1996a; Benson 1999). Furthermore, Kritzer (1995) has documented the creation of "flakes" produced by the heating cobbles and chunks of basalt and other medium to large-grained igneous materials that are virtually indistinguishable from actual debitage.

Because it is abundant, can be inexpensively traced to geologic source, and provides the opportunity to obtain an approximate absolute date, obsidian is particularly important for archeologists in northern California. Thus, a number of recent studies have addressed the effects of fire on the physical integrity, chemical composition, and hydration rinds of obsidian tools and debitage. In regard to the first, a number of analysts have noted macroscopic and microscopic alterations on obsidian specimens exposed to heat. Nakazawa (1999), for example, observed bubbles, vitrification, microfracturing, spotting, explosion, and breakage in laboratory and archeological specimens. Anderson and Origer (1997:18) noted that obsidian artifacts collected after a wildfire had been altered to the extent that visual sourcing was difficult to perform. The degree of physical damage appears to correlate not only with burn temperature and duration, but also the source of the obsidian. Steffen (1999) described extreme vessiculation (melting and frothing) in obsidian artifacts exposed to temperatures between 1300 and 1400° F during a wildfire event.

Obsidian collected from post-burn contexts has been chemically sourced with good success on a number of occasions (Deal 2001:5). However, Shackley and Dillian (1999) reported bonded sands on thermally altered obsidian from Arizona and New Mexico impeded traditional sourcing applications, while Skinner et al. (1997) had similar difficulties sourcing fire-effected obsidian artifacts in Oregon due silica-based encrustations.

Obsidian hydration rinds are affected as bonded water within the hydration band is released through exposure to heat. The result is diffusion of the hydration front and, at even higher temperatures, elimination of the band altogether. Thus, the hydration "clock" is reset and a particular artifact will appear too young based on obsidian hydration age. Skinner et al. (1997:10) also found that heat is capable of enlarging the width of the hydration rim at certain temperatures, making the obsidian hydration age appear too old.

Following a somewhat controlled experiment performed by Kelly and Mayberry (1979), most of the studies addressing this issue focused on post-burn observations at sites burned during wildfires or prescribed burns (e.g., Trembour 1990; Anderson and Origer 1994; Origer 1996). While largely lacking adequate control, these studies did demonstrate that obsidian artifacts recovered from areas that experienced severe fire behavior were more likely to have compromised hydration rinds than those from unburned or lightly burned locations.

More recently, a number of controlled studies documenting the effects of heat on obsidian hydration rinds have shed much light on this important topic. These studies, conducted in both wildland fire and laboratory contexts, indicate that a temperature threshold exists at or above which obsidian hydration data will be compromised. The duration of heat exposure may also have a role in effects, although this aspect is less well understood. Laboratory experiments, in which obsidian is heated in ovens at varying temperatures and intervals, have yielded very consistent results (Table ??). These demonstrate that visible alterations to the hydration rind begin to occur in some or all specimens at about 200° F, and above 300° F virtually all bands will be diffuse or totally absent. Interestingly, the study by Solomon (2000) revealed that hydration rind effects varied depending on the medium in which the artifact was placed; those in ceramic crucibles were less affected than those in or on sand at comparable temperature and duration of heating (Table ??).

Controlled experiments conducted in conjunction with actual prescribed burns are also informative (Table ??). These studies have typically involved placing artifacts with known hydration rind measurements in areas with low, moderate and heavy fuel loads along with temperature indicators like heat-sensitive tablets or thermocouples. Data are gathered regarding factors influencing fire behavior (e.g., fuel moisture, soil moisture, relative humidity, air temperature, wind speed and direction) and fire behavior is observed during the burn (e.g., flame length, rate of spread). Following the burn, the artifacts are collected, subjected to a second hydration analysis, and the pre- and post-burn readings compared. Two of these projects (Modoc NF, Boggs Mtn.) revealed temperature thresholds similar to those obtained in laboratory studies (about 400° F), two others showed some affects at lower temperatures (Toiyabe National Forest, Eldorado National Forest), while one (Willamette National Forest) appeared to be higher (Table ??). It is worth noting, however, that temperatures in the two studies with apparently reduced thresholds were obtained with thermocouples, whereas the others employed less accurate heat-sensitive tablets, crayons, and/or paints. Deal (1997:13) suggested that the duration of heating (long term smoldering/glowing combustion) along with uncontrolled variables (soil chemistry, roots, volatile oils, rocks) may have contributed to some of the anomalous results in the Eldorado burns, while Benson (1999:10) was inclined, at least to some degree, to accept the Toiyabe data at face value. Furthermore, as noted above, wildfire fire is a complex phenomenon, and it remains uncertain to what extent these conditions are replicated under laboratory environments.

Anderson and Origer (1997) offered the intriguing possibility that fire-effected obsidian hydration rinds might actually return to their original extent and configuration after a relatively short period of time. However, subsequent laboratory experiments attempting to induce re-hydration have produced equivocal results (Lloyd 1999).

Groundstone

Groundstone artifacts, including mortars, pestles, millingstones, handstones, ornaments and other varieties, occur in variable quantities at each of the NPS units in this study. Bedrock mortars and milling slicks are also found along the lakeshore at LABE.

Data on the effects of fire on groundstone are largely restricted to post-burn observations on sites burned over in wildfires. Lentz (1996b:63) reported that light severity burning had minimal effects on the surface of ground stone artifacts, whereas high severity fire results in sooting, oxidation, reduction and some adhesions. Pilles (1984) found that raw material composition of groundstone tools dictated the degree of fire effects; those made of sandstone frequently cracked, while basalt specimens subjected to the same fire intensity exhibited only blackening. For example, Wilson and DeLyria (1999) noted that basalt and andesite are more durable than quartzite (see also Latas 1992). Bedrock milling stations are also susceptible to fire damage; Keefe et al. (1999:112) documented spalling, exfoliation, cracking and smoke blackening on bedrock milling stations following major wildfires at Yosemite National Park, and noted that the extent of damage appeared to be positively correlated with the amount of fuel, and thus fire intensity.

Lentz (1996b:63) suggested that use wear, palynological, and macrobotanical data might be lost in groundstone specimens exposed to fire, and the loss of ground surfaces could compromise proper classifications (e.g., groundstone versus fire-cracked rock). A few post-burn observations and experiments on groundstone have yielded ancient residues, and some researchers feel that naturally and culturally fractured rock can be distinguished based on such variables as fracture patterns, differential on-site fuel loading, organic residue analysis, and luminescence of mineral constituents (Deal 2001; see below).

Shell

Marine and freshwater shell can occur in Native American (e.g., beads and ornaments, faunal remains) and historical (buttons, faunal remains) archeological contexts in the Northern California Subcluster. In northern California, shell beads and ornaments were most often fashioned from the shells of purple olive snails (*Olivella*), abalone (*Haliotis*), and a variety of marine clams. Freshwater clams were available at both LABE (Tule Lake) and WHIS (Clear Creek watershed). Shell beads and ornaments are useful for reconstructing aboriginal trade patterns, interaction spheres, and sociopolitical systems.

Various taphonomic forces that affect the integrity of marine and freshwater shell have been identified, ranging from chemical alteration to sediment abrasion (Waselkov 1987; Claassen 1991). Waselkov (1987:149) suggested that shell heated to a high temperature will begin to deteriorate as release calcium oxide mixes with sodium bicarbonate solution found in the soil.

Seabloom et al. (1991) found that shell exposed on the surface during a grass fire fractured or disintegrated. Haecker (2000:13-14) exposed a shell button and whole oyster shell to relatively low (ca. 475° F) and high (ca. 1,500° F) intensity fires. In the first, the shell button discolored and the oyster shell remained unchanged, while in the second, the shell button had completely calcined, and the oyster shell discolored slightly. Haecker (2000:12) further suggested that the morphology of the button contributes to susceptibility of fire damage, with small, thin types being the most vulnerable. It is important to note that shell beads and ornaments were sometimes intentionally heated or burned in anticipation of manufacture and/or prior to deposition (e.g., burned with a cremation). These may exhibit color and/or physical changes that reflect both cultural behavior, as well as greater vulnerability to subsequent heat exposure.

Bone

Archeological bone specimens occur in the form of culinary remains, formed tools and human remains at LABE, LAVO and WHIS. Faunal remains provide valuable information in regard to both human adaptations and past environmental conditions. Human remains have been reported from LABE and WHIS. Historically, the Modoc at LABE performed cremations during which the individual or individuals being interred were burned.

Thermal impacts include changes to the physical appearance and chemical structure of bone, the latter of which could potentially hasten the decomposition rate. Laboratory heating experiments performed on fresh bone produced significant non-water loss at 100° C, charring above 300° C, and extreme chemical structure alterations above 400° C (Bennett and Kunzmann 1985:12). McCutcheon (1992:360) found a loss of free water and some carbonization of organics up to 440° C, complete loss of the organic phase and loss of crystal-bound water between 440 and 600° C, and change in crystal size from 650 to 950° C in experimentally heated fresh bone. In laboratory-heated mammal, bird, and fish bone, Nicholson (1993) noted a general color shift from brown or black to gray and finally white between temperatures of 200 and 900° C. These changes were accompanied by morphological changes at both the macroscopic and microscopic levels.

While bone directly exposed to heat is clearly vulnerable, experiments performed by Bennett (1999) indicated that, under certain circumstances, shallowly buried bone could also be affected. The susceptibility of subsurface bone to impacts is influenced by the interaction of heat intensity, duration of exposure, and depositional sediment. Modern and archaeological specimens buried at a depth to 10 cm. and exposed to low intensity (<500° C) and long duration (up to 84 hours) burning exhibited color changes usually thought to be associated with higher temperatures and direct (rather than indirect) exposure to flame. Furthermore, those specimens subjected to high intensity, short duration exposure yielded notable color changes and moderate distortion. Stiner et al. (1995) documented carbonization in shallowly buried bone (≤5 cm.) located directly beneath a high intensity heat source (900° C), but none exhibited calcination.

Experiments performed by Stiner et al. (1995) demonstrated that burned bones are more fragile and brittle than unburned specimens, and that mechanical strength is positively correlated with the extent and intensity of burning. Bone fragmentation was particularly acute in burned specimens subjected to post-burn trampling.

Taylor et al. (1995) recently suggested that changes in the relative concentrations of certain constituent amino acids are manifest in bone subjected to one or more heating events, providing the specimen was not subjected to other significant diagenetic effects. It stands to reason that unburned bone subjected to sufficient heating during a prescribed or wildland fire may take on the above characteristics. Further, it was noted that other reactions, such as racemization, are highly affected by heating.

Observations of archeological bone specimens exposed to wildland fires indicated that even relatively low temperatures caused blackening and charring (Lissoway and Propper 1984; Seabloom et al. 1991). However, Seabloom et al. (1991) suggested that the degree of such alteration was less than that typically observed in bone that underwent actual cultural modification (e.g., burned in a hearth).

Pollen and Archaeobotanical Remains

While few archeological and paleoenvironmental studies in the Northern California Subcluster have focused on the recovery and analysis of pollen and archaeobotanical remains, these materials are present in certain contexts and comprise an important means of reconstructing human adaptations and past environmental conditions in the region.

Fire effects on pollen and archeobotanical remains have been examined in post-wildfire contexts. <<MORE>> Fire effects on pollen and archaeobotanical remains have been examined in post-wildfire contexts. Scott (1990) suggested that surface pollen was destroyed by moderately high intensity fire behavior, while subsurface pollen was relatively unaffected. Fish (1990), however, found that surface pollen, although physically altered, was still readily identifiable following the Long Mesa Fire.

Unless found in unique depositional contexts (e.g., caves and rockshelters), archaeobotanical remains are unlikely to be preserved in archeological unless carbonized (Micsikek 19??:219). Complete carbonization of plant materials occurs between temperatures of 250 to 500° C in low oxygen conditions. Carbonized plant remains are very resistant to further organic decay, often succumbing to nothing less than mechanical damage. Accordingly, Ford (1990) noted that wildfire did no apparent damage to botanical remains recovered from shallow fire hearths in sites burned during the La Mesa Fire. Eininger (1990:46), however, cited examples of other archeobotanical studies where the distinction between modern and archeological charcoal was far less apparent. Perhaps of greater concern in regard to archaeobotanical remains are indirect effects such as carbon contamination, which are discussed in more detail below.

Fibers and Hides

Fibers such as basketry and textile fragments, and animal hides typically occur only in very specialized contexts such as dry caves. These materials are highly susceptible to fire at even very low intensities (Ryan n.d.).

Rock Imagery and Spiritual Sites

Spectacular examples of rock imagery sites occur at LABE, and all three units contain or are suspected to contain Native American spiritual sites. Rock imagery sites at LABE include both petroglyphs and pictographs (Lee et al. 1988; Loubser et al. 1999). Spiritual sites encompass both tangible (e.g., Vision Quest markers at LABE [Eidsness 1997]) and intangible resources.

Romme et al. (1993) suggested that rock imagery panels are highly vulnerable to direct fire impacts due to exfoliation. Furthermore, the organic pigments comprising some pictographs could theoretically be damaged if exposed to fire.

Direct impacts to spiritual sites are less obvious. In the case of tangible resources like Vision Quest markers and rock cairns, potential damage might include spalling and cracking. Less apparent to most cultural resources managers are the effects fire might have on the spiritual significance of a particular site or location to contemporary Native Americans. This author has queried members of the Yurok and Klamath Tribes regarding this possibility, and informants have agreed that this is indeed a concern. Understandably, however, none were able and/or willing to elaborate on the nature of such impacts. Haynal (2000), however, documented the importance of rock cairns and prayer seats among contemporary Klamath/Modoc, and their desire to protect such sites from physical disturbance. Another apprehension with these areas is the presence of fire and other personnel in the vicinity of spiritual sites; this is discussed in greater detail below.

Use-Wear

Microscopic use-wear signatures have proven to be useful for interpreting the functions of certain prehistoric artifacts (SOURCE). <<MORE>>

Organic Residues

Organic residues that adhere to or are absorbed by artifacts, ecofacts, or features are the subjects of increasing sophisticated lines of inquiry (Heron and Evershed 1993; Orna 1996). Among the residues studied include lipids, proteins, carbohydrates, and other biopolymers. Although only infrequently applied in archeological investigations in the Northern California Subcluster (e.g., Bevill and Nilsson 1996; Nilsson et al. 1996), these studies will undoubtedly become more prevalent as costs drop and the interpretive potential becomes more widely known.

Heron and Evershed (1993) noted that certain residues are prone to elimination through pre- or post-depositional disturbance, including heating, although that aspect is poorly understood in archeological contexts. More recently, controlled experiments have yielded useful information. For example, based on an analysis of cooking pot residues, Malainey et al. (1999) found that fatty acid composition of plant and animal foods changed dramatically with thermal and oxidative degredation, rendering accurate interpretations difficult. Tuross et al. (1996) noted the paucity of protein residues preserved on experimental butchering tools, as well as the vulnerability of those residues to ultraviolet light exposure (see also Downs and Lowenstein 1995).

Newman (1995) reported positive immunological reactions on flaked stone artifacts recovered from sites in an area subjected to a high intensity wildfire. Still, it should be noted that there are many unknowns in regard to such studies, including the effectiveness and comparability of the various analytical techniques (Downs and Lowenstein 1995).

Glass

Glass in the form of complete artifacts and fragments are commonly found in historical archeological sites at LABE, LAVO, and WHIS. Glass bottles and jars can be used to date and assist in determining the function of archeological deposits (e.g., Rock 19??), while the mean thickness of window pane glass can be a useful temporal indicator. Some possible flaked glass tools have also been found on sites with Native American components as well. Heat build-up, smoke, and flames can all impact glass artifacts and fragments (Haecker 2000:7-9). Soda lime glass, commonly used for containers, windows, pressed and brown-ware and lighting products, has a melting temperature of about 1,000° F, while lead glasses melt at 785° F. Crazing, or cracking of glass into smaller, irregular segments, is a common impact associated with exposure to heat, though the degree of effects is related to the type and thickness of the glass, temperature, and distance from the point of origin.

Metal

A variety of metal artifacts have been documented at all three NPS units, including cans, nails, cartridges, telecommunication lines, fencing wire, automobile parts, wood stoves, horseshoes, coins, utensils and building materials. Taken as a whole, these materials provide a tremendous amount of information regarding chronology and lifeways (e.g., Rock 19??).

Haecker (2000:10-12) noted that certain metals may actually melt prior to reaching their melting points (Table ??) through the process of alloying where a metal with a lower melting point drips onto one with a higher melting temperature, the resulting reaction lowering the melting temperature of the latter. Metal artifacts that do not melt may warp out of shape under certain conditions.

Haecker (2000:11) noted that many historical metal artifacts and features have previously been subjected to the effects of fire through trash burning, structure fires, etc. While many of these were probably not of sufficient temperature to adversely damage metal artifacts, certain components (e.g., lead solder in cans) may have melted, causing a loss of structural integrity and hastening disintegration. Likewise enamel and plating (such as tin, brass and silver) can burn or spall off, exposing the underlying metal to oxidation. Even heavy-duty metals, such as iron and steel, are subject to pitting and other surface damage that can result in long-term attrition. Copper and brass ammunition cartridges, with their high melting temperatures, are generally impervious to fire, although Haecker (2000:12) documented an incident at the Little Bighorn Battlefield where unfired cartridges detonated when exposed to a grass fire.

Fire-related impacts to metal artifacts in the Northern California Subcluster are probably most acute on the earliest sites. For example, at WHIS, mid to late 1800s mining features are scattered about the landscape, most of which appear to lack associated artifacts with which to place the site in temporal context. Upon closer inspection, however, many of these do contain can scraps, nails and other small metal fragments, most of which are already heavily degraded. Even low intensity fire in these areas could eliminate the artifacts altogether.

Thermal shock is another potential impact to metal artifacts and features. This occurs when heated metal is subjected to sudden cooling through the application of water. For instance, cast iron heated to temperatures below 1,000° C will crack when rapidly cooled. This may also expedite the oxidation process.

Historical Ceramics

Ceramic artifacts and fragments are found at habitation sites on occasion. Potential fire effects are dictated by the characteristics of the paste, glaze, painted decorations, as well as the temperature to which the artifact is exposed (Haecker 2000). Refined (i.e., glazed) earthenwares (e.g., ironstone, hotel wares) will crack and become discolored at even relatively low temperatures. Porcelains have a melting temperature of about 2,820° F, although overglaze paint decorations and makers marks can become discolored and/or eliminated, thereby potentially compromising the ability to accurately identify and/or date the artifact.

Cement, Brick, and Cinder Block

These common building materials are frequently found in association with historical archeological sites. Haecker (2000:7) suggested that porous firebrick is highly susceptible to fire, and that cinder block, certain masonry surfaces, and cement mortar could spall when exposed to fire. Experimental heating performed on gypsum plaster, fire brick, and cement mortar revealed varying effects depending on fire temperature. At about 475° C, the firebrick and cement mortar were unchanged, and the gypsum plaster was discolored and friable. The firebrick discolored and broke, gypsum plaster became even more friable, and the cement mortar discolored at temperatures exceeding 1200° C. Keefe et al. (1999) recorded damage in the form of spalling and cracking on concrete features burned over during a wildfire event.

Wooden Features and Artifacts

Wood occurs on a number of sites at LABE, LAVO and WHIS in the form of standing and collapsed structures, fence posts, miscellaneous artifacts and scattered lumber. Haecker (2000:2) noted that the rate of wood charring, the carbonization of a fuel by heat or burning, varies widely depending on a number of factors (Table ??). Typically, a section of dimensional lumber will ignite at about 660° F. Haecker (2000) further noted that wood occurring in historical archeological contexts is particularly susceptible to even low-intensity burning because it is often highly decomposed due to weathering and located in close proximity to other highly flammable materials (e.g., thick vegetation, accelerrents).

Vegetation

Culturally-modified trees are known or suspected to occur at all three of the units, although none have been formally documented. For example, consultants with the Klamath Tribes are aware of modified juniper trees within LABE, perhaps associated with the manufacture of bows (cf. Wilke 1989). Stands of large black oak trees are often found in close proximity to mid-elevation habitation sites at WHIS, suggesting that these areas were utilized and tended by native inhabitants. <<Basque Carving at LAVO>> <<Blazes>> The potential for fire to damage culturally-modified trees is related to the condition and health of the tree, surrounding fuel load, and, in some instances, method of ignition (e.g., aerial vs. ground). In general, dead or dying trees are the most likely to be impacted by even a low intensity burn.

Exotic ornamental, fruit and nut trees, shrubs, and perennial and annual flowers are common components of historical habitation sites throughout northern California. Among the species commonly represented in the Northern California Subcluster are apple, pear, cherry, and walnut trees, English and German ivy, roses, Himalayan blackberry, <<MORE>>. These species probably have varied susceptibility to long and short term fire effects.

Tree ring data are invaluable in regard to fine-grained paleoclimatic and paleoenivironmental determinations (Fritz 1976). Furthermore, standing trees and stumps of certain species can yield excellent fire history data (Arno and Sneck 1977; Barrett and Arno 1988). The latter application has been utilized at WHIS (Gibson 1999) and LAVO (Taylor 2000). Cultural resource managers in the American Southwest have long been cognizant of the potential for fire to damage tree ring data (e.g., Lissoway and Propper 1988:5; Eininger 1990:47-48; Romme et al. 1993; Lentz 1996c:94). In the southern Sierra Nevada, Giant Sequoia stumps comprise not only historical archeological and landscape features, but are also critical sources of long-term climatic and fire histories (e.g., Swetnam 1993). Depending on the condition of the stumps and surrounding fuel loads, stumps can be very vulnerable to damage or complete destruction during wildland or prescribed fires (T. Caprio, personal communication 1997).

Packrat Middens

Packrat middens occur throughout western North America and comprise a valuable tool for paleoenvironmental reconstruction (Betancourt et al. 1990). Content analysis of packrat middens in lava tubes caves at LABE have provided valuable information on vegetation shifts on the western margin of the Great Basin (Mehringer and Wigand 1987; Miller and Wigand 1994). Packrat middens frequently contain wood and other flammable plant remains. Although most probably occur in areas of sparse or little fuel (e.g., caves and rockshelters), organic materials could potentially be ignited by spotting or intense convection heating (Romme et al. 1993).

Leather

Leather occurs in the form of shoes, clothing and horse tack in the Northern California Subcluster. With age, these objects dry and become brittle and will char in a low intensity fire and be consumed at higher temperatures (Ryan n.d.; Haecker 2000:12).

Rubber and Plastic

Rubber and plastic artifacts are often found on more recent historical sites. Rubber and rubberized artifacts are completely consumed in low intensity fires, while plastics melt between 75 and 265° C (Haecker 2000:11, 12).

Operational Effects

Although generally thought of as being associated only with wildfires, operational effects can also occur in conjunction with prescribed burns and WFRBs. In general, a tremendous amount of potentially damaging activity is involved in the implementation, control and/or suppression of wildland fires (Pyne et al. 1996). Traditionally, those operational effects involving ground disturbance have been the focus of cultural resource managers. Indeed, many of the early archeological surveys conducted in anticipation of prescribed burns in the Northern California Subcluster focused exclusively on mitigating pre-burn ground disturbance (see Volumes II through IV). Additional operational effects considered here include less obvious impacts that include ignition techniques (which influence burn intensity and rate of spread), chemical and physical influence of fire retardants, and looting.

Fire Lines

Fire lines are breaks in fuel continuity, of which there are several varieties (Table ??). DO-18 dictates that all prescribed, WFRB, and wildfires have some form of finite, delimited boundary. Generally these boundaries are comprised of a combination of natural (e.g., rock outcrop, river) and human-made (e.g., road, handline, wet line, catline) phenomenon. Often, fire lines are constructed in anticipation of (prescribed burn) or during (wildfire) a fire event. The Urban-Wildland Interface Initiative of 200? encouraged the construction of fire lines at strategic points to assist in the containment of future wildfires. Finally, even when natural and human-made boundaries are employed, some form of fireproofing is usually carried out along these features such as live vegetation thinning, removal of dead-and-down fuels and felling of hazard trees.

LABE, LAVO and WHIS have adopted a relatively consist standard for fire lines constructed in the context of prescribed fire. At LABE, <<MORE>>. At LAVO, ????.

<<Line Placement>>

Line construction is far less systematic during wildfire events. Heavy equipment has been utilized recently at both LABE and WHIS, resulting in some documented resource damage (see below). More often, however, hand crews are employed to construct lines similar to those described above. In many instances, multiple crews are simultaneously operating in multiple locations, sometimes at night, and often without the supervision of a professional archeologist. Depending on conditions, these lines are constructed in order to attain *direct* control of the fire (containing it to extinguishment), or *indirect* control (securing the perimeter of the burn from strategic boundaries) (Fig. ??). Potential advantages of the former include minimization of fire size and immediate control, while poor control over line placement is the principal drawback. Indirect control results in less line construction and better control over line location, but allows for a larger fire.

Wettstaed (1993; Wettstaed and LaPoint 1990) documented a variety of impacts to archeological sites related to fire line construction under wildfire conditions in Montana. Twelve previously unrecorded archeological sites were exposed through the construction of 53 miles of fire lines with bulldozers. These lines ranged from one to seven or eight blade widths wide (to 30 m. or more). One site was exposed to a depth of one meter in a cut performed to gain access to a local water source. The remains of numerous fire hearths were observed in berms that lined the cuts. Siefkin et al. (19??) also documented extensive bulldozer damage on a late prehistoric habitation site in the foothills of the southern Sierra Nevada. Though at a smaller scale, the construction of fire lines with hand tools can also have an adverse effect on site integrity (e.g., Keefe et al. 1999).

Staging

Staging occurs in prescribed, WFRB and wildfire contexts. Staging involves the distribution of people and equipment before, during and after the fire event.

In prescribed burns, the number of personnel and equipment is usually fairly low compared to wildfires, and not always positively correlated with the size of the burn unit. Rather, the complexity of the burn and proximity of the burn unit to developments and other important resources generally dictates the amount of support required. Staging in prescribed burn units located close to developed areas often occurs in previously disturbed areas such as roads, parking lots, and pullouts. Vehicles are parked in these areas, and equipment, such as hoses and drip torches, is readied. Ground disturbances, though usually very shallow, can result in these areas. Staging of all-terrain vehicles, equipment and personnel will also take place on constructed fire lines, and these are also used to access various portions of a burn unit.

In more remote locations, established trails often function as access and travel corridors to and within a burn unit. Spike camps might be placed at established backcountry camps, or new ones created at optimal places. Ground disturbances might include increased foot traffic, and the excavation of latrines and pits for gray water disposal. A heli-spot or drop spot is often located nearby, and these will be constructed (by clearing vegetation) if necessary. Staging requirements are generally similar for WFRBs.

Staging under wildfire conditions, however, is frequently more complex owing to the frequently urgent nature, larger numbers of personnel, and greater variety of equipment. While vehicles and other equipment are often driven and parked in designated and/or previously disturbed areas, the sheer number can lead to a greater potential for resource damage. For example, during the Kanaka Fire at WHIS in 199?, several bulldozers were staged within NRHP-eligible archeological site CA-SHA-177 resulting in extensive surface damage (SOURCE). Personnel are generally housed at large temporary base camps. These are often located a substantial distance from the actual fire, and usually in developed areas like campgrounds and large parking lots. Spike camps are established on the margins of the burn, and are utilized by field personnel which, on large conflagrations, can number in the hundreds. If no suitable areas exist, one or more heli-spots and drop locations will be constructed. In the absence of vegetation-free areas, safety zones are sometimes constructed along the perimeter of the wildfire. They are used by fire fighting personnel in the event of extreme fire behavior. Safety zones can be substantial in size (hundreds of square meters) and will be cleared of all standing and ground fuels with hand tools.

Disturbances associated with staging vary between prescribed burns, WFRBs, and wildfires. In general, not only is the amount of ground disturbance higher in wildfire situations, the locations chosen for heli-spots, spike camps and safety zones are often made with little advanced planning or notice. Substantial ground disturbance can occur as a result of heavy equipment operations, while such impacts tend to be largely restricted to the surface when only hand tools are employed.

Ignition Techniques

A variety of ignition patterns are employed when conducting prescribed burns and suppressing wildfires (Pyne et al. 1996), all of which have implications for archeological resources. Heading fires are those with a front line spreading or set to spread with the wind or upslope. Heading fires are generally ignited in spots or strips and allowed to spread (Fig. ??). These fires are rapid, inexpensive and result in good smoke dispersal, but result in a high intensity fire with high spotting potential. Backing fires are ignited along a baseline (e.g., fire line, road, stream) and allowed to back into the wind or downslope (Fig. ??). Spot and strip ignition patterns can also be employed with backing fires. Backing fires are generally low intensity, have slow spotting potential, and spread slowly. Flanking fires are used to treat an area with lines of fire set directly into the wind. Multiple individuals ignite strips that form a series of widening triangles, or chevron (Fig. ??). Flanking fires provide a means of keeping flame heights between those of heading and backing fires, but require a lot of coordination to safely implement. Finally, center or ring fires involve the ignition of the center of the burn area, followed by concentric rings of fire surrounding the central point. This method is rapid, has excellent smoke dispersal, burns at a high intensity in heavy fuels, and is susceptible to long distance spotting. Each of these techniques is employed to some degree within the Northern California Subcluster.

Insofar that fire intensity and rate of spread may influence the direct impact of fire on cultural resources (as discussed above), consideration of the method of firing is very important. However, the modes of ignition should be considered as well. Ground and aerial ignition are the most common forms of ignition used in the Northern California Subcluster. Ground ignition is accomplished through the use of fusees, drip torches, and ???, with one or more individuals involved in firing operations. The use of flanking and heading ignition methods causes fire personnel to actually enter the interior of the burn unit. Aerial ignition sources include ping-pong ball machines and heli-torches. <<Affects of Aerial>> Often both types are utilized during prescribed burns. For example, the boundaries of a unit will be secured with hand ignition, followed by aerial ignition of the interior portion. As noted, heading fires and center or ring fires carry the potential for long distance spotting, comprising a potential threat to cultural resources located downwind.

Fire Retardants

Several types of fire retardants have seen use during prescribed and wildfires. These fall into two general groups-physical agents and chemical agents (Pyne et al. 1996). The former influence heat and diffusion processes, whereas the latter affect fuels by modifying the course of combustion. Physical agents, such as water and dirt, typically provide short-term protection against combustion. Typically water is combined with additives that either reduce surface tension (i.e., wetting agents) that allow treated water to penetrate deeply into combustible material, or increase water viscosity (i.e., thickening agents) so that treated water congeals on the surface of fuels. The latter is considered particularly effective, and often delivered by aircraft as a gel or slurry. Chemical agents afford long-term protection, and are also generally applied as slurries.

Fire retardants have been successfully used to protect archaeological resources from the direct effects of fire. For example, at Sequoia and Kings Canyon National Parks, foam applied to *Sequoia* stumps effectively prevented damage to these features. <<MORE>>

The operational effects of fire retardants on cultural resources relate to their application and composition. Backback pumps, fire hoses, and aircraft are often used to apply fire retardants. Weight of aerial, distance of drop Romme et al. (1993) speculated that slurry or water dropped from aircraft could topple standing walls of prehistoric structures, and the same could probably be said of wooden historical features. Likewise, high elevation retardant drops could also impact midden deposits and artifact scatters. Some fire retardants are corrosive and/or toxic.

The former is a concern in regard to the application of foams, gels and slurries on cultural resources such as historical structures and features. <<MORE>>

Mop-Up and Rehabilitation

Mop-up and rehabilitation occur once a fire has been declared controlled and out, respectively. These are carried out most often following wildfires, often under the direction of a BAER team. Some mop-up and rehabilitation may take place after prescribed burns or WFRBs. Depending on circumstances, mop-up varies from a concerted effort to extinguish all combustion through intensive hand labor to ground patrol to aerial reconnaissance. The aggressive approach can be particularly detrimental to cultural resources. This involves extensive ground disturbance through the use of hand tools, hazard tree felling, and hose work. In forested areas, smoldering tree roots and stumps are often excavated and broken up.

Wettstaed (1993; Wettstaed and LaPoint 1990) described heavy damage to an archeological site resulting from mop-up activities, including extensive subsurface disturbance and artifact breakage resulting from tool blows. Traylor et al. (1990) found that mop-up following the La Mesa Fire produced surprisingly little damage to archeological resources, and none to architectural remains.

Rehabilitation involves reconditioning fire lines and other disturbed areas, stabilizing volatile landforms, and controlling runoff. This is accomplished using a combination of hand tools, heavy machinery, and aircraft. Fire line rehabilitation associated with prescribed burns is often as simple as pulling back (with hand tools) the berm adjacent to the scratched line and, when not constructed within a shaded fuel break, perhaps disguising the course by scattering cut vegetation. On larger fire lines, such as those constructed by bulldozers, heavy equipment is often needed to correct the damage. Wettstaed (1993; Wettstaed and LaPoint 1990) suggested that rehabilitation in these instances could result in significant, if unrecognized, damage to cultural resources. For example, rehabilitation of a fire line that passes through an archeological site will return artifacts to the footprint of the line, but out of original context. Given enough time, it might prove difficult to identify any previous impacts, especially if the lines were not mapped. Traylor et al. (1990) reported similar woes from rehabilitation following the La Mesa Fire, and the restoration of bulldozer lines in particular.

Emergency measures are often employed after wildfires to stabilize hillslopes, stream channels and roads (Robinchaud et al. 2000; USDA and DOI 2001a, 2001b). As described in greater detail below, extensive research documents that surface runoff and erosion can increase markedly following a large, moderate to high intensity wildland fire. Among the most commonly employed hillslope treatments include grass seeding, contour-felled logs, mulches, fabrics, scattered brush, and silt fences. Previously employed channel treatments are straw bale check dams, log check dams, rock dams, log and rock grade stabilizers, in-channel debris basins and clearing, and stream bank armoring. Road treatments consist of outsloping, culvert removal and upgrading, rolling dips, water bars and others. Some of these, such as contour-felled logs, contour trenching, outsloping and channel clearing, might require the use of heavy equipment and will result in extensive disturbances.

<<Arch BAER team stuff>>

Looting

Looting is a threat to cultural resources during and following prescribed burns, WFRBs, and wildfires. A major dilemma for cultural resource managers is the disclosure of sensitive information to fire personnel; on one hand, people need to know where and what resources to protect and/or avoid them, but on the other, it opens the door for inadvertent and malicious damage. In locations where cultural resource density is high, such as the American Southwest, it is nearly impossible to suppress a wildfire or conduct a managed fire without communication between fire and cultural resources management personnel in order to prevent resource damage.

Traylor et al. (1990:103-104) found surface artifact collecting to be a common phenomenon during the La Mesa Fire, and that fire personnel were often unaware of laws against collecting. However, it was also noted that fire personnel were extremely receptive to educational messages provided by archeologists associated with the event. MORE

Sacred sites

Indirect Effects

Indirect fire effects are a potential threat to archeological resources following all prescribed and wildland fires. <<MORE>>

Increased Surface Runoff and Erosion

As noted, research indicates that surface runoff and erosion can increase markedly following a fire (Robichaud et al. 2000:5-11). Under good hydrological conditions (>75 percent of ground surface covered with vegetation and litter), only about two percent or less of rainfall becomes surface runoff and erosion is low. Severe disturbances, such as large, moderate to high intensity fires, can render poor hydrological conditions (<10 percent of ground surface covered with vegetation and litter), the result being up to a 70 percent and 300 percent increase in surface runoff and erosion, respectively. These effects can be particularly acute and wide-ranging if the fire is closely followed by precipitation. A water-repellent hydrophobic layer sometimes forms on the ground surface following a fire, exacerbating the impact of even moderate rainfall. Under such conditions, even raindrops become agents of localized changed. While surface runoff and erosion will dissipate with the return of vegetation, but recovery can be slow (order of decades) following severe fires and/or in xeric vegetation communities.

Under the right topographic, soil, and climatic conditions, increased surface runoff can lead to dramatically higher stream peakflows and sediment delivery. Higher stream peakflows generally lead to higher stream levels, one consequence being elevated erosion rates on landforms adjacent to the streambed. At WHIS and LAVO these localities tend to support the highest density of prehistoric and, in some cases, historical archeological resources, the integrity of which are threatened during high water events. <<EXAMPLE>>. Riparian resources of ethnographic significance such as willows and bulrushes can be impacted, at least on the short-term, by high flows. Raised sediment loads often have an adverse affect on certain fish populations like salmon.

Soil loss resulting from surface erosion degrades water quality, alters geomorphological and hydrological characteristics, and reduces site productivity. Along with this, the spatial integrity of archeological resources is threatened, particularly those located on or adjacent to slopes. Experimental studies and field observations attest to the combination of sheet erosion (induced by water, wind and other phenomenon) and gravity as an effective conveyor of artifacts and ecofacts (e.g., Rick 1976; Schiffer 1987). Following extensive wildfires in Montana, Wettstaed (1993; Wettstaed and LaPoint 1990) found that a localized heavy downpour produced a puddling effect on one site, concentrating flaked stone debitage into pools that might later be mistaken for reduction loci. The impacts of more extreme events such as mass wasting are often more striking in regard to cultural resources. The landscapes at LAVO and WHIS are replete with evidence from such actions, some of which may have been initiated or at least exacerbated by wildland fire.

Unit stuff

Increased Tree Mortality

Trees can perish during fires due to tissue damage resulting from exposure to heat (Miller 2000:9-16). In some cases, trees are killed outright, in others individuals are weakened and succumb to disease and insects. The susceptibility to fire mortality and injury varies by species; for example, Giant Sequoia and ponderosa pine are highly resistant, western juniper, incense cedar and white fir highly vulnerable, and sugar pine somewhere in between. Each of the Northern California Subcluster unit's considered in this study explicitly identify the reduction of certain fire-intolerant tree species (e.g., western juniper at LABE, firs at LAVO and WHIS) that have proliferated due to fire suppression, and a decline of overall stand-density as high priorities (SOURCE).

While tree mortality is an inevitable process, fire, in combination with other factors, can lead to rates that exceed those believed to be "natural." Under severe wildfire conditions, vast areas have seen morality rates as high as ?????. Long-term research conducted in prescribed burn units in mixed conifer and Sequoia groves in the southern Sierra Nevada showed that tree density declined 40 percent one year following a prescribed burn, and reached nearly 50 percent after ten years (Keifer 1998). The relative density of white fir and red fir reduced nine percent and eight percent after 10 years, respectively, while Giant Sequoia density increased 16 percent during the same time span. With the exception of the largest diameter trees (>1 m.), all diameter classes of white and red fir exhibited notable declines one year after prescribed burns.

The implications of high tree mortality are several. Trees killed outright or severely weakened by fire are very susceptible to falling over. Those located within or adjacent to archeological resources could do severe damage by dislodging materials found in or around the root wad, or artifacts and features can be crushed or disturbed by the main trunk or larger branches. Likewise, branches can also be driven deeply into the soil as the tree strikes the ground, potentially impacting subsurface components. Finally, fallen trees comprise heavy fuels that will burn at extreme temperatures during a future fire event.

Examples

It is important to note that tree mortality impacts are of particular concern at the present time since large tracts of the three Northern California Subcluster units have not seen fire in several decades. As a result, tree densities are high, and species with low fire tolerance are often overly represented. Duff and wood fuel loads are also high. Inevitably, prescribed or wildland fire in these areas will result in high tree mortality. Fire monitoring research in the conifer forests of the southern and central Sierra Nevada revealed that woody fuel accumulations can reach 75 to 100 percent of the pre-burn levels after about 10 years (Keifer 1998). Presumably, however, as stand density is reduced through repeated and consistent application of prescribed or wildland fire, pre- and post-burn fuel loads will be lowered significantly and may never again reach present levels.

Looting

Increased Burrowing Rodent and Insect Populations

The affect of burrowing rodents and insects on the integrity of subsurface archeological resources is often under appreciated (e.g., Wood and Johnson 1978; Erlandson 1984; Bocek 1986;

Schiffer 1987; Pierce ????; Armour-Chelu and Andrews 1994). Animals that reside and forage almost exclusively in subsurface contexts (e.g., gophers, earthworms) can cause substantial vertical and horizontal movement of sediment constituents, blurring distinctiveness between strata, separating and combining unassociated items, obscuring subtle features, exposing previously buried archeological materials on the surface, and transporting exposed artifacts below surface. Physical alterations to artifacts and ecofacts such as breakage and abrasion have also been noted. Animals and insects that reside mostly on the surface, but do some burrowing (e.g., rabbits, coyotes, foxes, ants, badgers) can produce similar types of damage, through perhaps on a lesser scale. Most of these disturbances are restricted to the upper two meters of the soil profile.

A number of studies have documented the volume of sediment displaced by burrowing animals. Smallwood and Morrison (1999) reported that excavation rates among several species of pocket gopher (*Thomomys* sp.) vary widely; estimates for *T. bottae* (which occur at WHIS) ranged from six to more than 80 m.^{3} ha/year, while *T. monticola* (found at LAVO) varied from more than 13 to 615 m.^{3} ha/year. Worms etc.

Research suggests that the populations of burrowing rodents will increase following prescribed and wildland fires (Lyon et al. 2000a:28). Rodent populations often remain high after the fire because the animals are protected within burrows. The quantity of preferred forage is also enhanced by fire in most habitats, again promoting high survivorship and increased populations (Lyon et al. 2000b). Accordingly, populations of rodent predators such as coyotes will also increase, and these species can also disturb significant amounts of soil in the quest for prey. Insects etc.

<<Unit specific>>

Increased Microbial Populations

Romme et al. (1993) cited research suggesting that microbial populations increase following fires (e.g., Bissett and Parkinson 1980; see also ???), and that these organisms might have a detrimental effect on the preservation of the archeological record. Recent studies demonstrated that microorganisms are indeed present in bone samples, although the implications for taphonomy are not yet clearly understood (Child 1995, 199?).

Carbon Contamination

The contamination of archeological sites and features with non-cultural carbonized botantical remains is an issue of major concern. In the context of radiocarbon dating, submission of recent charcoal would yield an erroneously late determination. In terms of the reconstruction of economic systems and paleoenvironments, introduction of recently burned plant remains like acorn hulls and grass seeds could result in misleading interpretations.

Archaeologists have become far more cognizant of the integrity of charcoal assays submitted for radiocarbon analysis. Schiffer (1986; 1987) pointed to the “old wood problem,” the submission of conventional radiocarbon samples obtained from charcoal that is far older than the actual episode of occupation (e.g., recycling of wooden beams in architecture of the American Southwest, use of driftwood as firewood), as a potentially serious problem. The advent of AMS dating provided archeologists with an opportunity to submit far smaller charcoal samples, often a tiny fragment of gracile vegetation such as a shrub, with the implication that this would have far less of a chance for long-term preservation than more substantial vegetation, and therefore more accurately date the period of occupation in question. That this is an issue worthy of attention, a recent analysis performed on charcoal AMS samples from Daisy Cave on San Miguel Island (which supports no burrowing rodents) demonstrated that ???? (Erlandson et al.

199?). The potential implication in prescribed and wildland fire contexts is that charcoal, from both trees and lighter vegetation, will be extremely abundant after a burn, and that this can enter archeological context through the action of fire itself (e.g., burned tree roots) and/or subsurface disturbances (e.g., rodent burrowing). Even if great care is exercised when selecting charcoal AMS samples, the potential exists that the most desirable sample material could be a product of recent fire activities.

Based on the analysis of carbonized botantical remains from sites burned over in the La Mesa Fire, Ford (1990) suggested that distinguishing cultural and natural charcoal was relatively straightforward. The former were thoroughly carbonized, exhibited no textural or color differences, and were more friable, while the latter were consistently harder, varied greatly in terms of combustion, and often only scorched or burned on a single surface. As a caveat, the La Mesa samples were obtained relatively soon after the area had burned. Given enough time, recent charcoal may well take on the characteristics of older material, and the survivorship of more thoroughly carbonized modern charcoal would be favored. MORE

Discussion

It should be clear from the presentation above that that prescribed and wildland fire and its consequences do have the potential to adversely impact cultural resources. It is also apparent that "impacts" fall along a user-defined continuum which relates strongly to those resource values considered important and worth protecting (Jackson 1997; Deal 2001:2-3). In the case of direct effects, fire can result in the complete elimination of an artifact or feature (e.g., through consumption) or can alter attributes of an artifact or feature such that important research (e.g., obsidian hydration rinds, residues on pottery, bone burning), traditional (e.g., Native American spiritual sites) or other values are impacted. Obviously one is no better or worse than the other, and the nature and scale of fire impacts to be accepted or mitigated against in a particular region, district or unit will depend on decisions made by the scientific community, resource managers, Native Americans, the public and others.

Several problems and misconceptions accompany our understanding of the effects of fire on cultural resources. One is that standard predictive models, like BEHAVE, used by fire managers to anticipate fire behavior for particular fuel models and climatic conditions do not yield data that can be easily employed to predict potential damage to cultural resources. Fire intensity measures from the typical BEHAVE output include variables such as flame height, rate of spread and fire line intensity (expressed in BTUs), while thresholds of damage to archeological resources are available almost exclusively in temperature degrees. Too few studies have been performed that link fire behavior data with temperature to make anything other than the most general inferences, not to mention the difficulty of accounting for the complexity of actual fire behavior. The implication is that predicting the direct effects of fire on many cultural resources amounts to little more than guesswork and that strict reliance on the established thresholds in an effort to generate "safe" prescriptions is probably inappropriate.

A frequent comment heard by cultural resources managers dealing with fire is, "Everything *must* have burned in the past, so why are you worried about it?" While this certainly could be the case, there are several reasons why it is not a sufficient reason disregard or downgrade mitigation efforts. First, has everything burned in the past? Although fire history data from most regions in North America indicate that fire was formerly more prevalent in time and space, this is not enough to demonstrate that all cultural resources have been subjected to fire. Indeed, nothing should be considered to have burned unless proven empirically. Fire history data also show that past fires tended to burn in a patchy, mosaic-like fashion, with the implication that not everything burned during every fire, or perhaps even the majority of fires in a given area. Further, even if material did burn, fire history data also suggest that fires in the past were much less intense than the conflagrations of today, with the potential that damage did not occur or was minimal. Because artifacts, features and other resources are the products and byproducts of human behavior, it is often the case that these were deposited in areas manipulated by humans. A common form of manipulation includes the intentional or unintentional elimination of vegetation through burning, clearing, trampling and other means, and that material deposited in those locations could have been subjected to even less intense fires. In intensively occupied areas like villages, little or no vegetation may return after decades or even centuries, providing another measure of protection against hot fires. Finally, even high and moderate intensity wildfires that have occurred in recent times tend to also burn heterogeneously, meaning that one cannot simply assume a site or feature found within the boundaries of a historic wildfire was affected by that fire.

One also needs to consider that the archaeological record is not a stable phenomenon, being subject to alteration by a variety of cultural, natural and physical processes (Wood and Johnson 1978; Schiffer 1987). As demonstrated above, only under certain circumstances do the direct effects of fire extend much more than a few centimeters below the ground surface. Therefore, those artifacts and features near or on the ground surface are susceptible to fire impacts. Due to cultural, natural and physical processes, material that entered the archeological record in a subsurface (e.g., a burial) or surface (e.g., pot drop) context are unlikely to be relegated to that provenience in perpetuity, and might be expected to shift between the two on multiple occasions. One should not always assume, therefore, that an artifact found on the ground surface was there 500 years ago, 50 years ago, or even yesterday, or that buried artifacts or features have been thus for any length of time. The age(s) of the material also bears consideration in that, all else being equal, the older resources will have had more opportunity to be exposed to fire effects than more recent ones, and that this holds true for prehistoric, historical and ethnographic elements.

Finally, just because cultural resources have been impacted by fire does not negate their importance in a traditional, scientific, or interpretive sense. Indeed, an obsidian projectile point whose hydration rind was compromised by a past fire can still provide valuable information in regard to type, obsidian source, location, condition, and a host of other variables. An 1880s trash dump may have burned several times in the past, but the bottle fragments it contains are sufficiently intact to derive technological and chronological information. In all of these cases, subsequent application of fire, whether managed or not, and especially if fuel loads are great and/or weather conditions extreme, could destroy those remaining attributes that are most important (e.g., projectile point shatters, bottle fragments melt).

Some have even argued that artifacts and features burned in past fires have tremendous data potential. For example, Deal (1997) suggested that obsidian could be a useful tool for determining past fuel loads and fire events in the northern Sierra Nevada. Since the vast majority of surface collected obsidian artifacts retain readable hydration rinds, it is implied that few, if any, moderate or severe intensity fires occurred prior to modern suppression. Deal (1997:18) speculated that if a hydration rind eliminated or diffused in an obsidian artifact burned over in a past fire event began to rehydrate, the width of the latter band might be used to "date" the fire event in which the artifact was initially impacted. If valid, among the intriguing possibilities of this application is the expansion of fine-grained fire history data beyond that offered by tree rings. Again, and regardless of the nature of the data, subsequent fire events offer the potential to adversely impact data retained by previously burned artifacts and features.

CHAPTER 4
APPROACHES TO FIRE-RELATED COMPLIANCE

It is probably not misleading to suggest that there are as many approaches to fire-related compliance as there are agencies conducting prescribed burns. The reasons for this are several. First, the fire effects data are equivocal and open to interpretation. Second, fire effects are in many cases "invisible" and can be easy to ignore. Third, the exponential growth in Federal prescribed fire programs has outpaced the ability of cultural resource managers to thoughtfully address management considerations. Fourth, perhaps due to the reasons above, a top down approach to standardized compliance procedures has only recently been implemented, leaving individual units, districts, bases, and forests to largely fend for themselves. Finally, because of all of the above, State Offices of Historic Preservation are also ignorant of the potential effects of fire, and therefore ill-equipped to adequately evaluate submitted compliance documentation. <MORE>

Recently, several attempts have been launched to develop programmatic approaches to prescribed fire compliance. Since 199?, the NPS, in conjunction with the ???, has attempted to develop a nationwide Programmatic Agreement between the national and state offices of historic preservation (Gleeson and Jones 1999). Completion of this document, which is intended to be augmented with specific compliance needs of a particular unit, resource area or forest, is due to ???

One successful example of a programmatic approach, if only conceptually, is that developed by Jackson (1997) for the National Forests of the Sierra Nevada in the Pacific Southwest Region. The various aspects of this approach are presented below. This is followed by a more general discussion of the topic in reference to the needs of the Northern California Subcluster, and sets the stage for the unit specific treatments presented in Volume II through IV.

Prescribed Fire and the Protection of Heritage Resources in the Sierra Nevada

The principle components of this module are presented in Table ??. <<MORE>>

Identifying the Undertaking

Jackson (1997:12) recommended that at least six to 12 months lead time be provided for the completion of cultural resources compliance for a given prescribed burn, and the larger the burn, the greater the lead time. Such time will also allow inclusion of cultural resources data in NEPA documentation. While some prescribed burns may be considered categorical exclusions under NEPA,

Resource Values of Interest

CHAPTER 5
RECOMMENDATIONS

Fire Monitoring Program

Following mandates presented in DO 18, RM 18, and the National Environmental Policy Act (NEPA), the NPS fire monitoring program was developed to accomplish a suite of objectives (Table ??) ranging from the acquisition of basic information to providing direction for fire and resource management programs. The recently completed Fire Monitoring Handbook (USDI, National Park Service 2000) provides standardized methods from which to document, monitor, and manage wildland and prescribed fire.

Notes

1 At the opposite end of the subsistence-settlement continuum, Binford (1980) identified hunter-gatherer groups that practice no or little food storage, choosing instead to move main settlements to more productive locales when the resources in the vicinity of the current settlement are depleted. Called foragers, these groups are most commonly found in temperate forest regions where seasonal resource imbalances are less pronounced. Archeological research in northern California suggests that forager-type adaptations may have been present at various points in the past, particularly the early and middle portions of the Holocene (SOURCES).

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